

# Identification and Analysis of Partial Shading Breakdown Sites in $\text{CuIn}_x\text{Ga}_{(1-x)}\text{Se}_2$ Mini-Modules

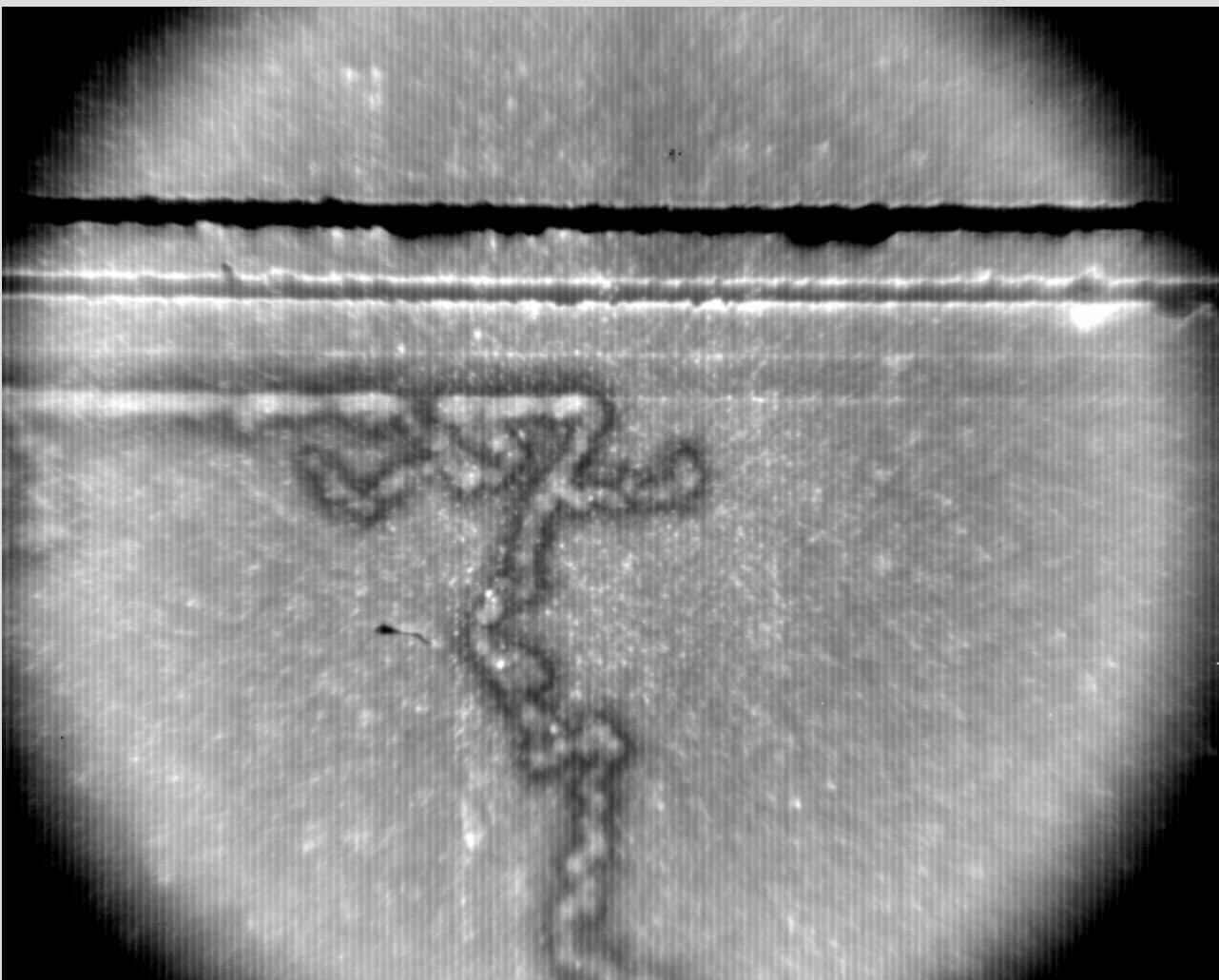
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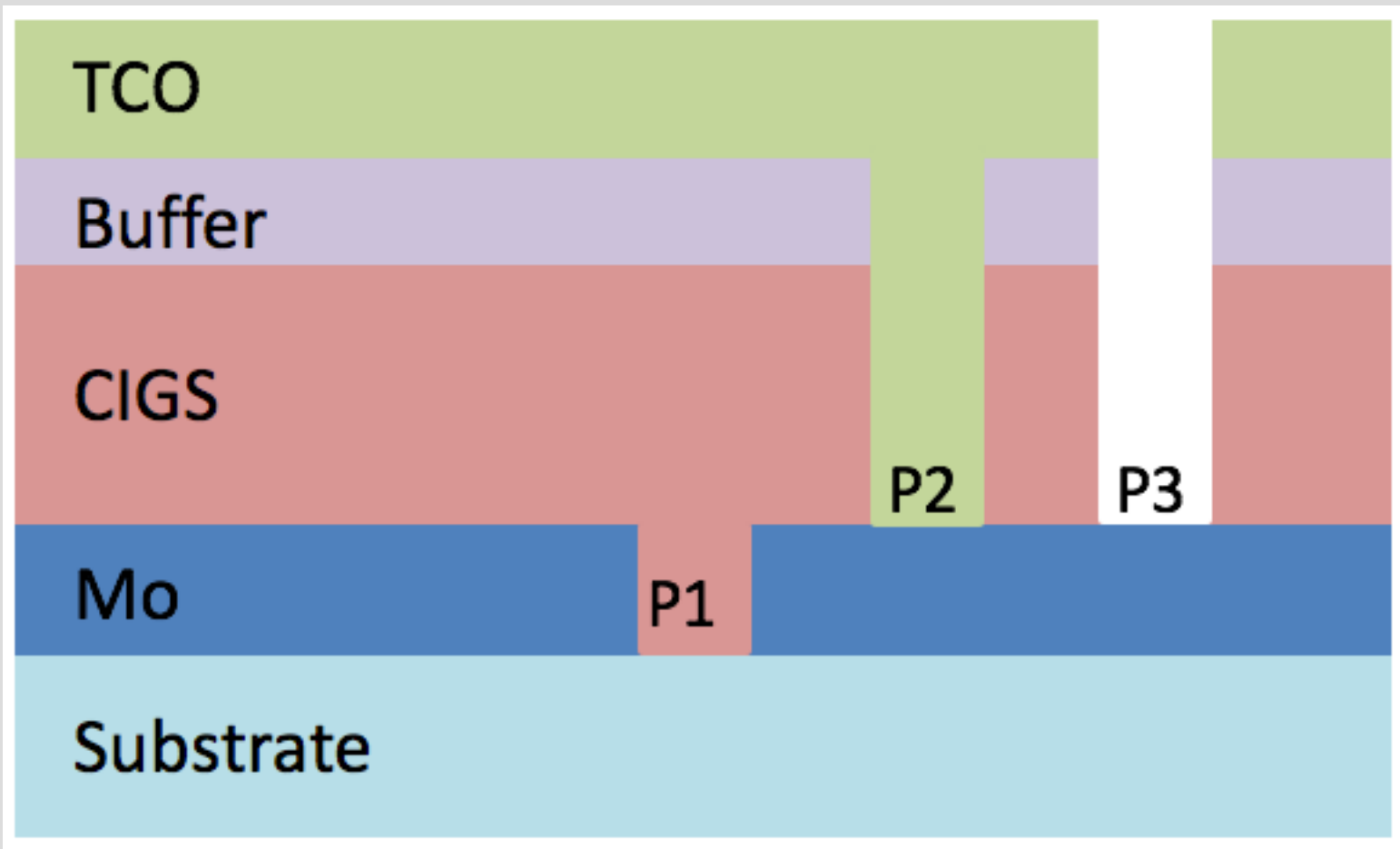
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## Study

This study replicated partial shading conditions across CIGS mini-modules by reverse-bias stressing to characterize resulting failure. Localized thermal runaway and breakdown results in ‘wormlike’ permanent defects. EL and DLIT imaging and current-voltage curves were used to study these sites.



‘Wormlike’ defect on CIGS mini-module.



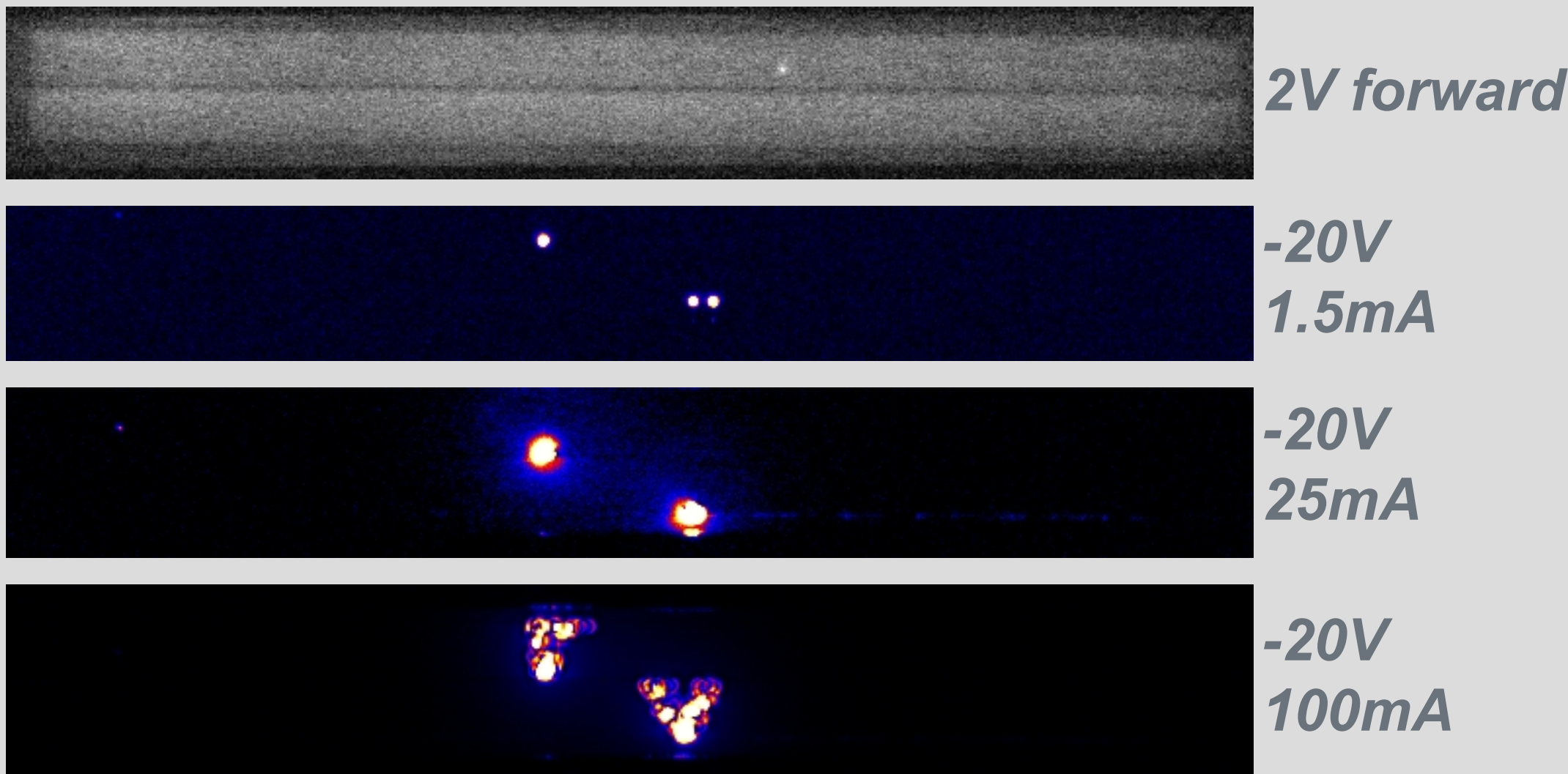
CIGS structure, defining the scribe lines.

## Statistics

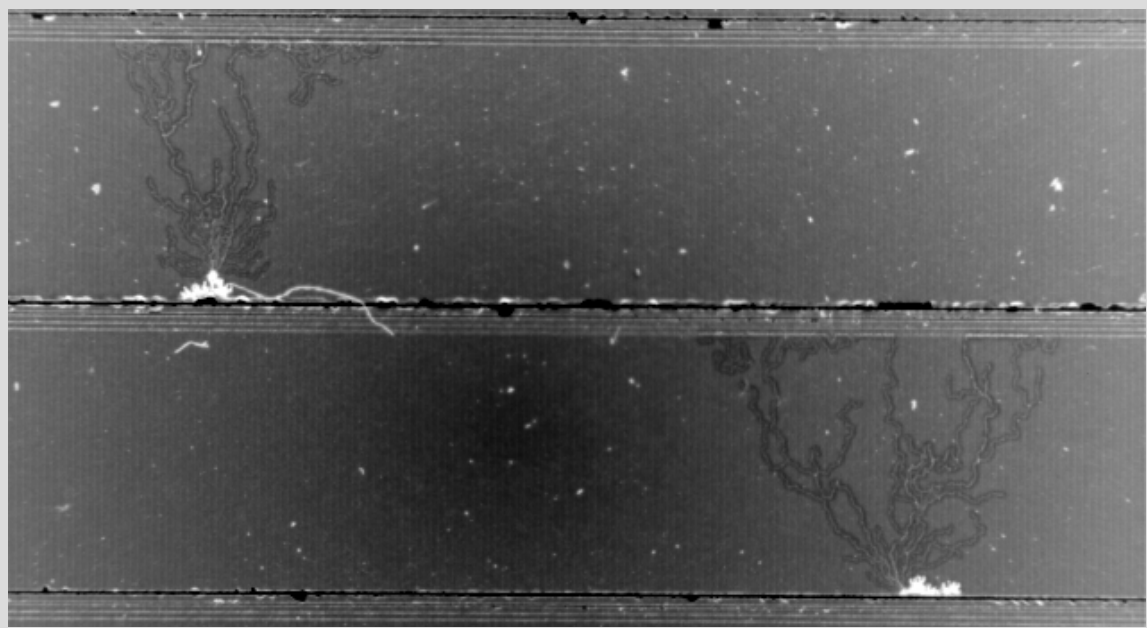
		Company 1			Company 2	
		Module 1	Module 2	Module 3	Module 1	Module 2
	Predicted	4	9	10	12	12
	Correct	4	9	10	11	12
	Not Predicted	0	1	2	4	0
by thermal analysis	On Scribe	2	5	5	9	10
	In Cell	2	4	3	5	2
by optical analysis	P1	1	0	2	0	4
	P3	0	2	0	0	0
	cell to P1	1	4	0	0	0
	cell	1	1	1	13	6

Statistics summarizing predicted breakdown sites by hotspot identification, actual breakdown sites, and breakdown location.

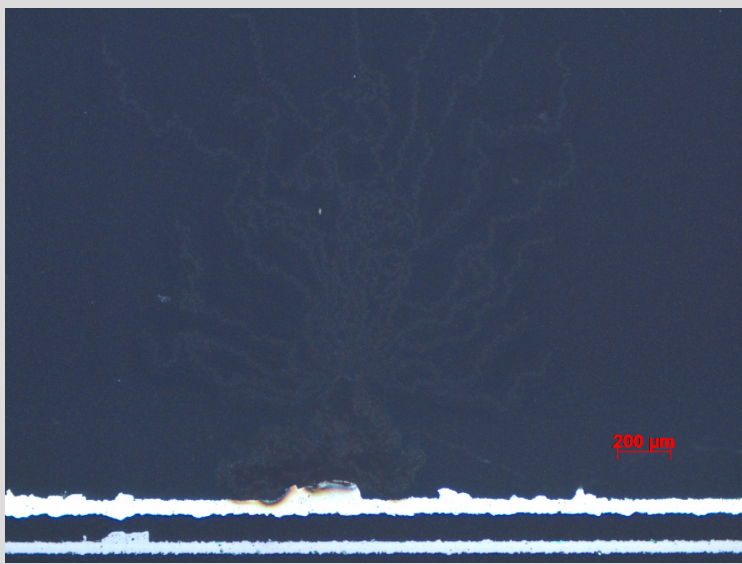
## COMPANY 1



DLIT images of reverse-bias stressing of c4c5 of Module 5.

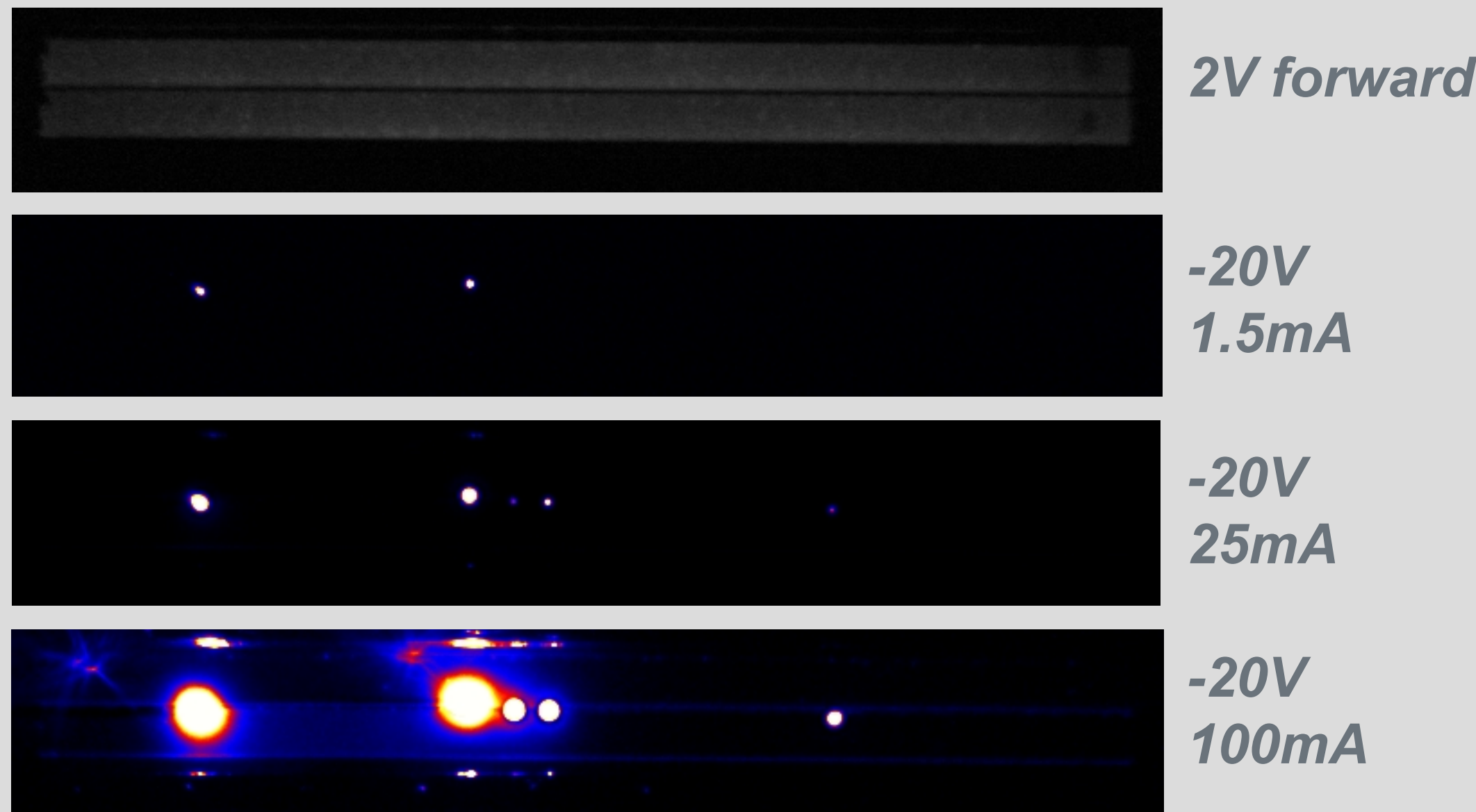


Thermal image of wormtrails from breakdown of cells 4 and 5 of Module 5.

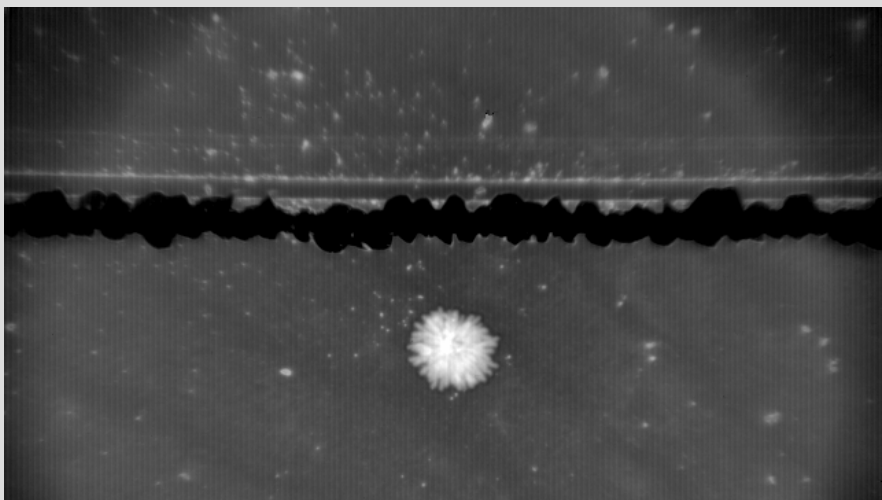


Optical image of cell 4 wormtrail.

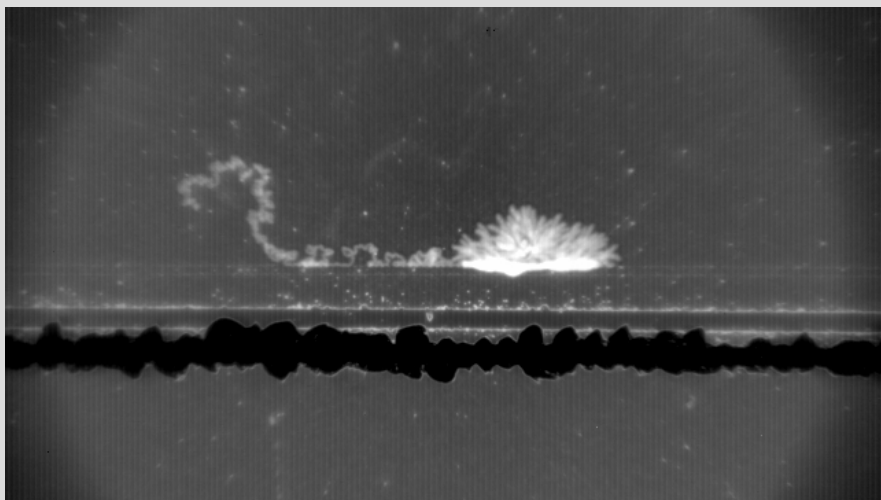
## COMPANY 2



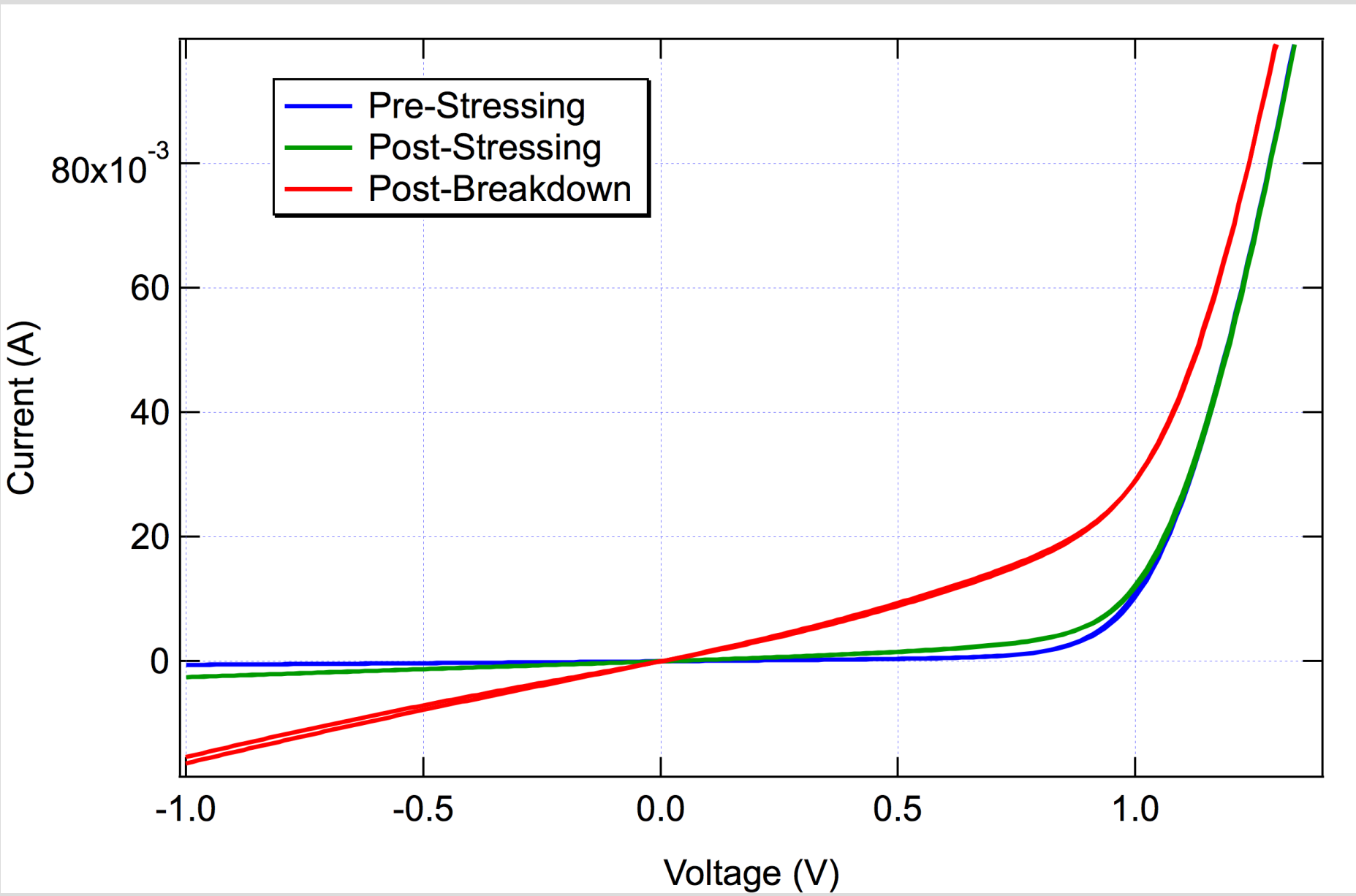
DLIT images of reverse-bias stressing of c9c10 of Module 2.



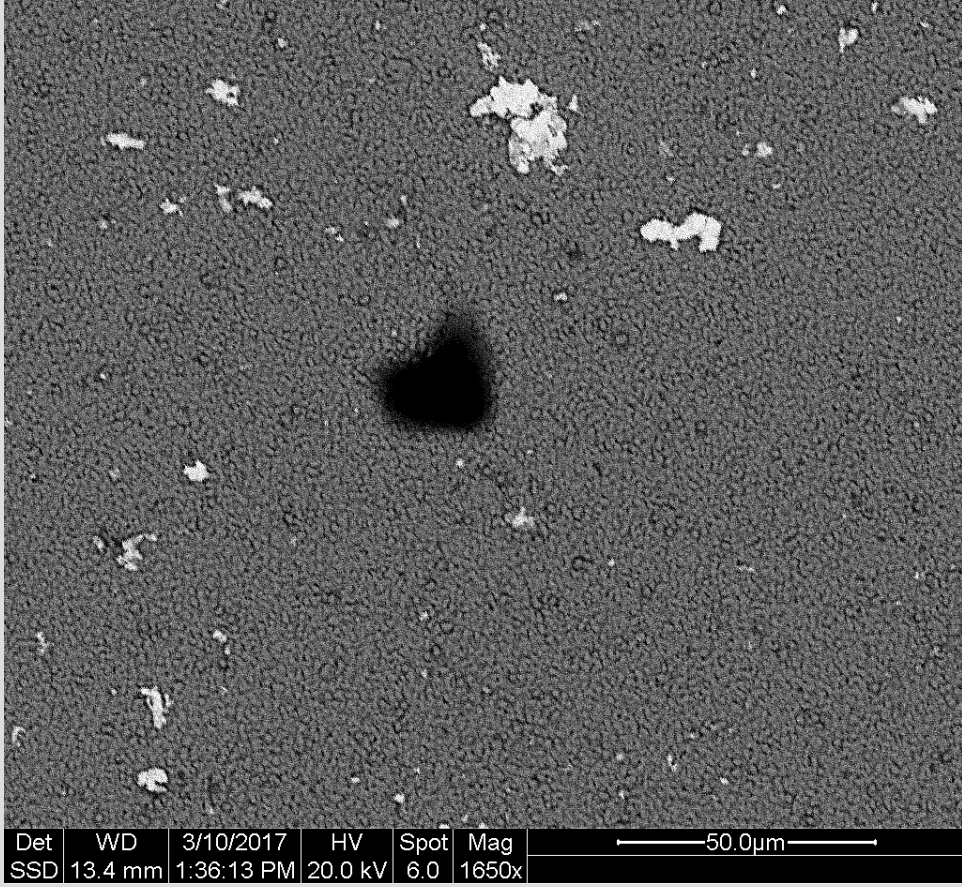
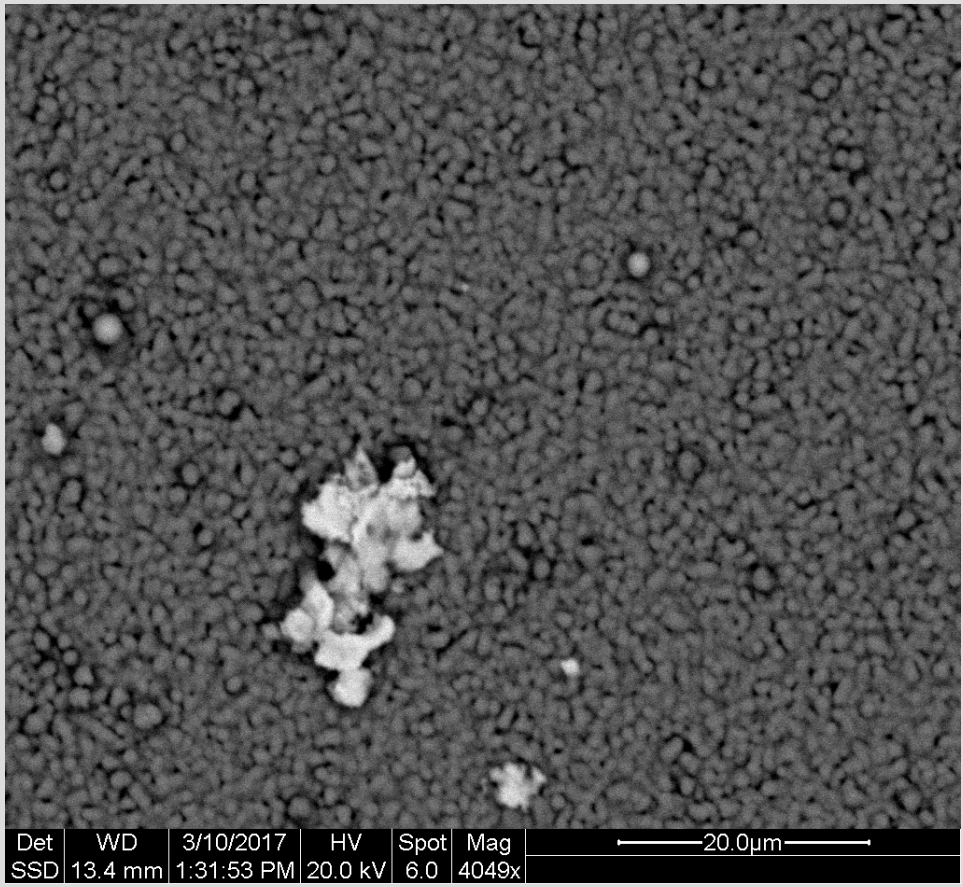
Wormtrail of left-most breakdown site.



Wormtrail of right-most breakdown site.



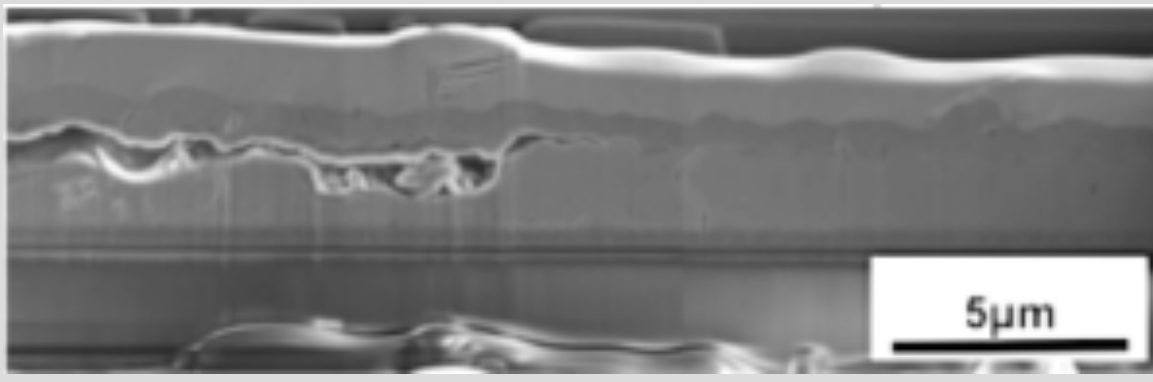
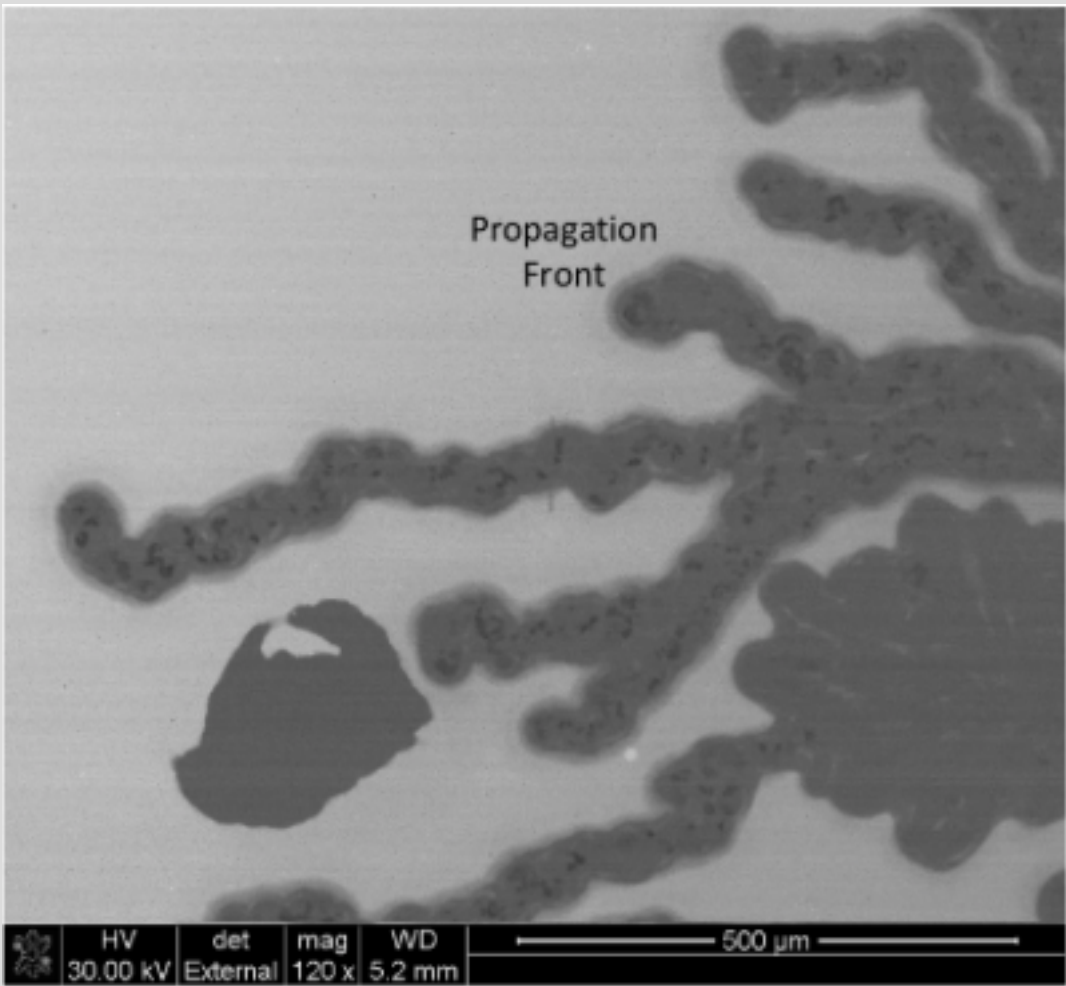
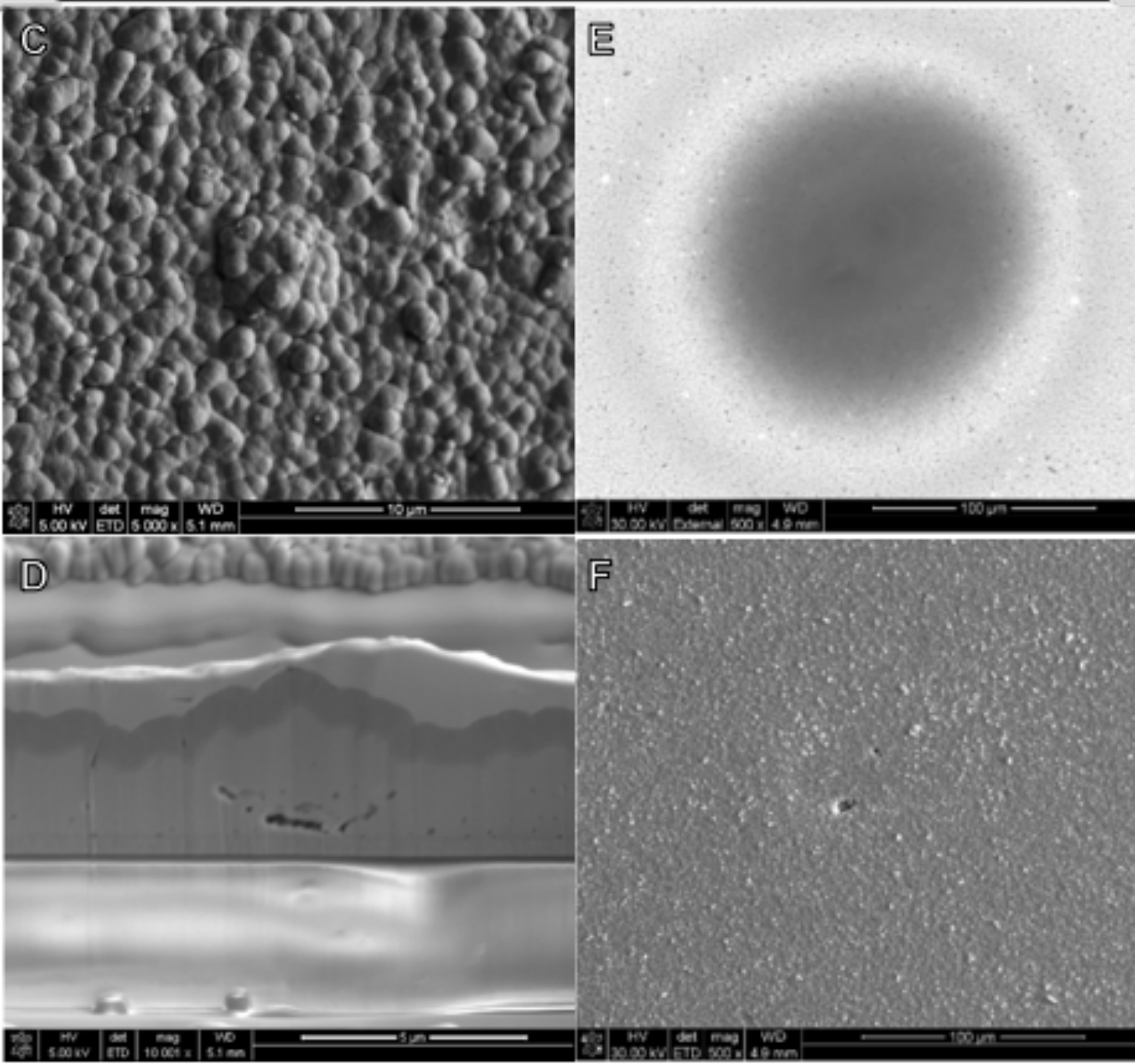
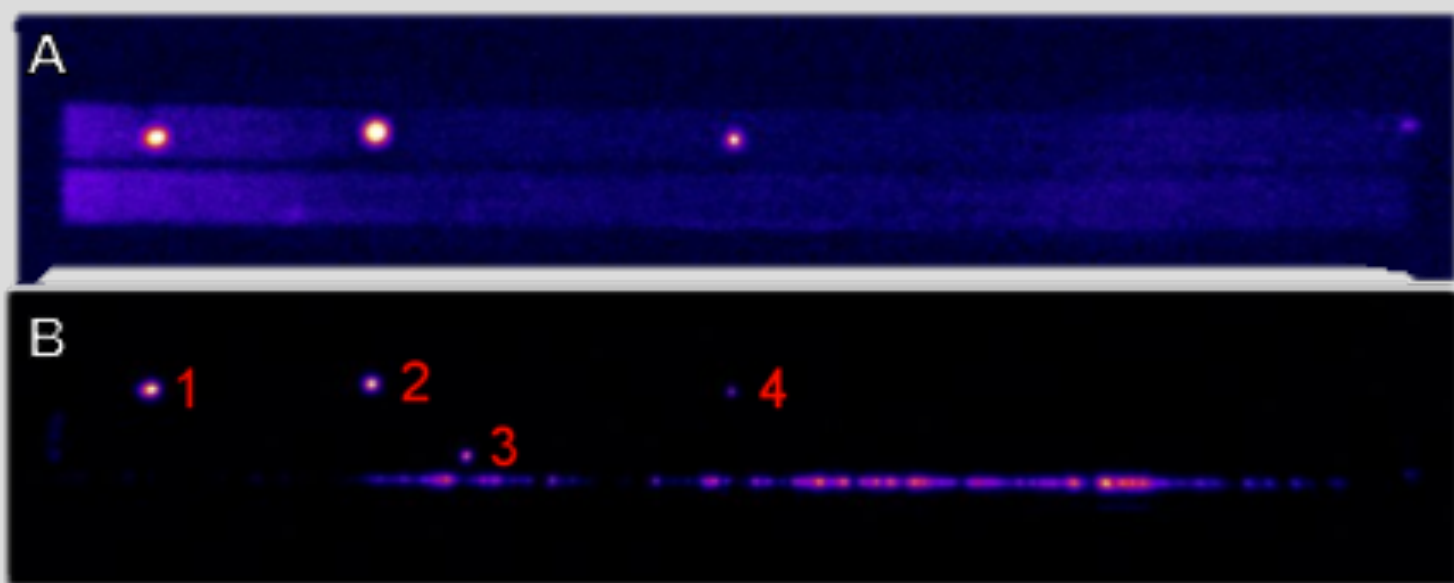
## ESEM



ESEM/EDS was performed on localized hotspots and revealed no areas of concern on the module surface.

## FIB

Different imaging techniques were used to analyze two stressed cells. A and B are the forward and current-limited reverse bias cells, respectively. C and D are the SEM and FIB cross-section of defect 3, respectively. E and F are EBIC and SEM images of defect 4, respectively. Defects 1, 2, and 4 are crater-like. Defect 3 is nodule-like.



SEM and FIB images originating in a permanently damaged wormtrail and moving into the non-damaged region.

## Summary

- This study:
- Developed a new technique to predict where failure in reverse-biased CIGS cells will occur
  - Provided statistics in regard to where failure will occur
  - Found that failure occurs in lower layers of CIGS